Formaldehyde Integrated Path Differential LIDAR

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Opto-mechanical design: Andrew Swanson

Program: IIP-ICD-19

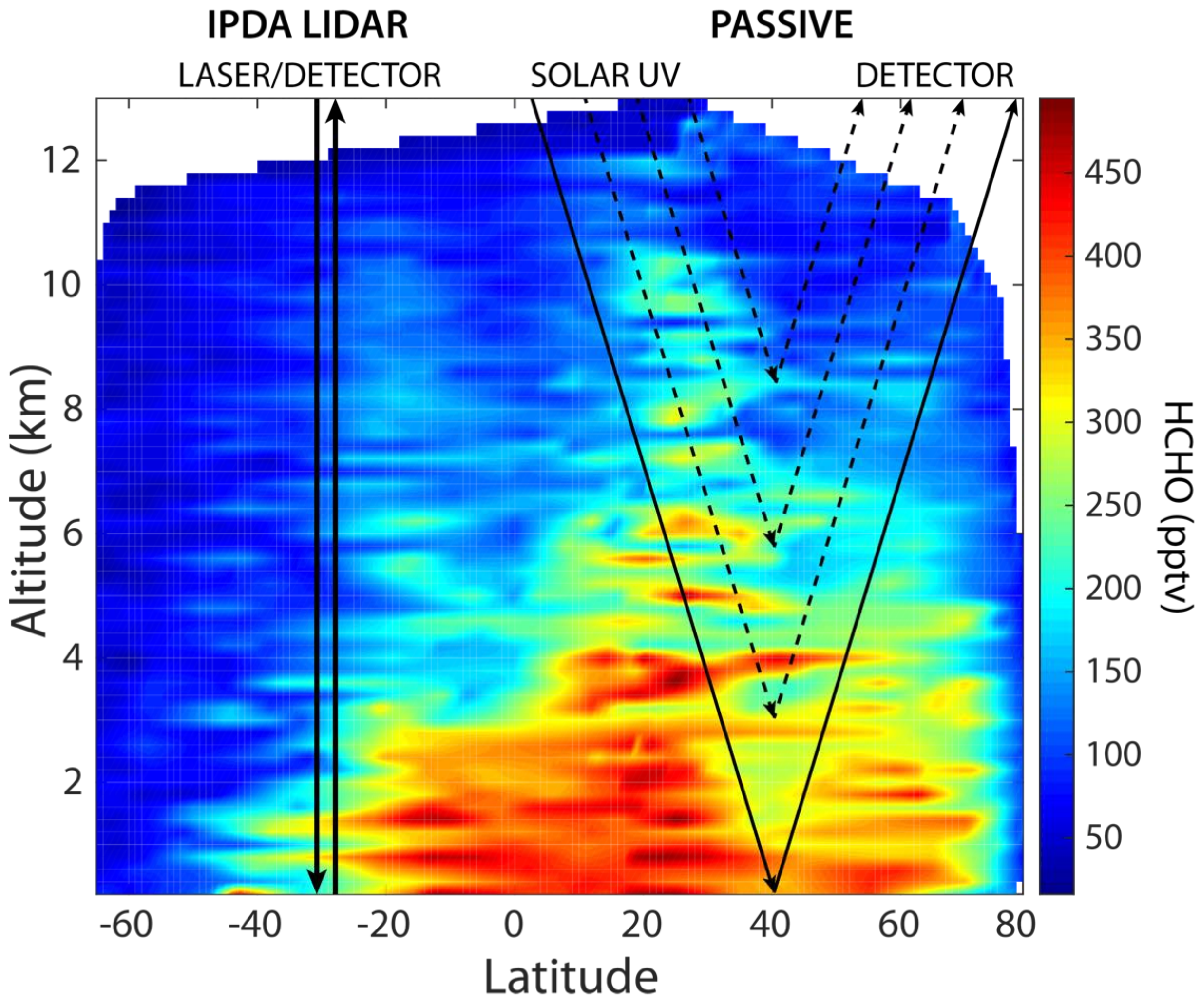
Problem to Solve

Formaldehyde is important for Air Quality

- Ozone (O_3) Nitrogen Dioxide (NO_2), and Formaldehyde (HCHO) are the three main “Air Quality” gases measured from space.
- Ozone (smog) is produced from NO_2 (the oxidizer) and volatile organic compounds (the fuel)
- Formaldehyde is produced from the degradation of volatile organic compounds (VOCs)
  - It is a surrogate for the large number of biogenic and anthropogenic VOCs that we cannot measure.

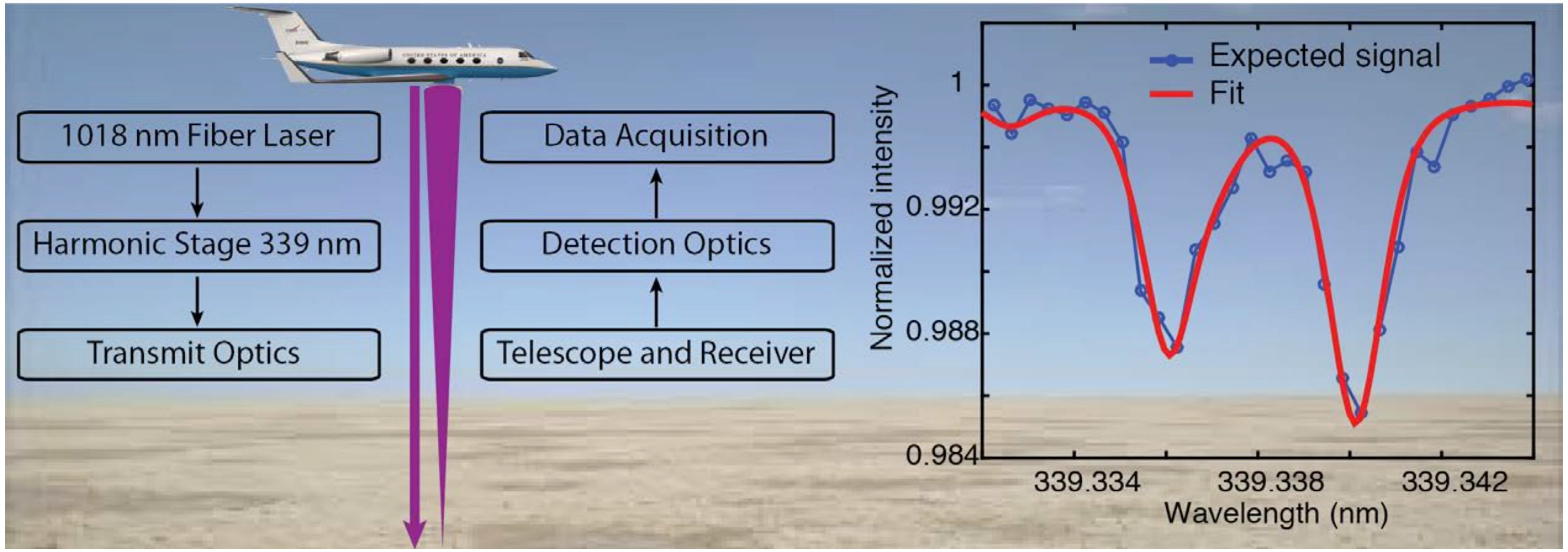
HCHO Retrieval

- Passive sensing of formaldehyde is challenging
  - Scattering can dominate return in UV
  - Highly dependent on profile (modeled *a priori*)
  - Different models can result in 40% difference in the retrieved column
- Active sensing has simple retrieval
  - complicated technology
  - ESTO solution



Solution

- **Concept:** "Integrated Path Differential LIDAR"
- **Method:** Tunable laser scans over rotational features. Beer's Law analysis to determine column abundance of HCHO
- **Challenge:** low abundance of HCHO
- **Mitigation:** HCHO science is "+/- 20%" science

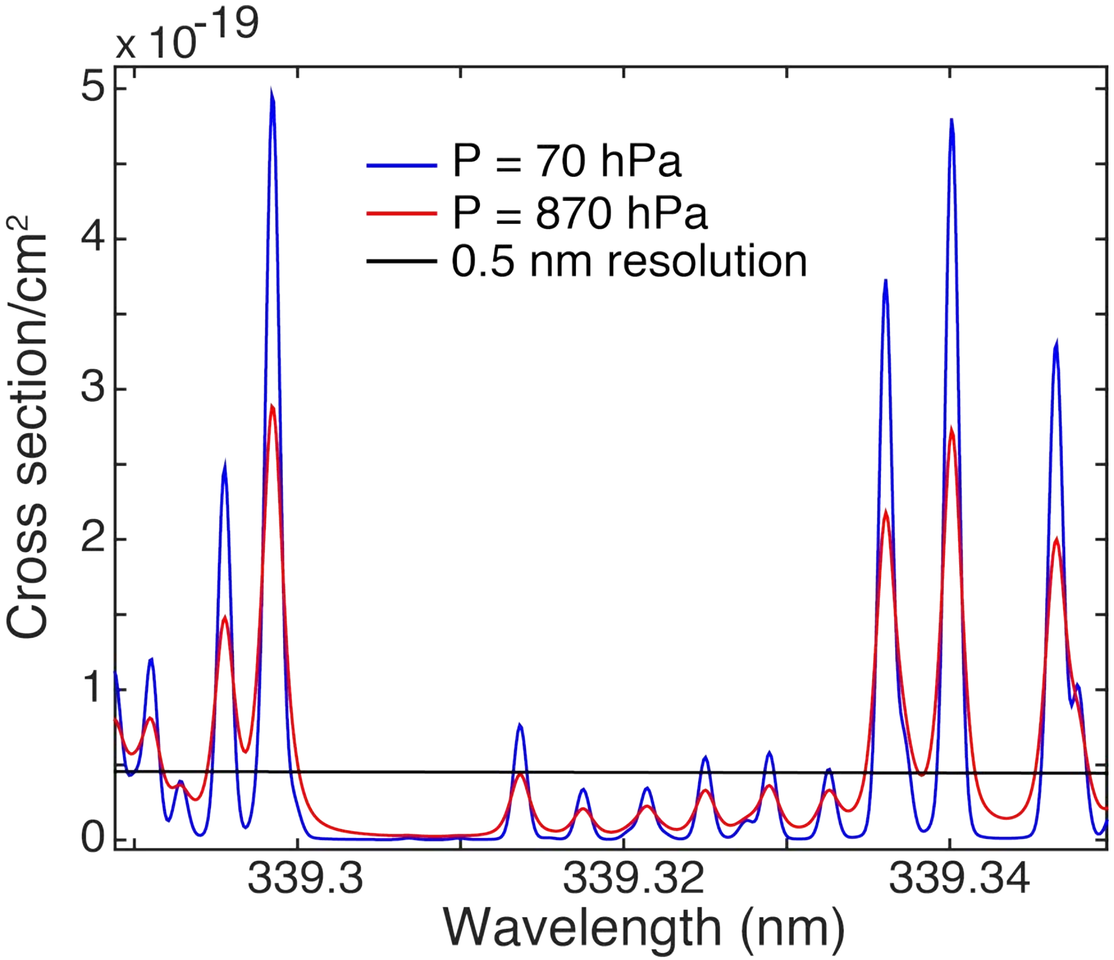


Spectroscopy

Rotational spectroscopy provides sensitivity and specificity

- HCHO rotational transitions are 5-10 times stronger than the average integral (0.5 nm used in passive)
- Pressure dependence is weak compared to scattering weights
  - Linestrength ~x2
  - Scattering ~x10

Significance: IPDA is 5-10 times more sensitive to HCHO and 5-8 times less sensitive to the *a priori* than passive sensing



Laser Transmitter

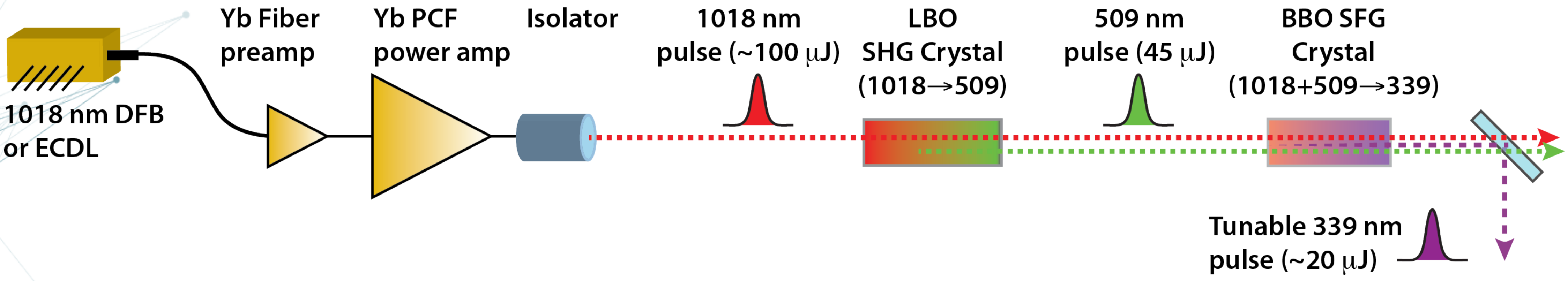


Table 1. Nominal performance parameters for the HCHO Airborne IPDA LIDAR

Laser wavelength	340 nm	Laser linewidth	<0.001 nm	Laser Power	2 W
Laser pulse width	~10 ns	Pulse energy	20 mJ	Repetition rate	100 kHz
Beam divergence	1 mrad	Laser scan range	0.05 nm	Laser scan rate	250 Hz
Receiver diameter	20 cm	Receiver FOV	1 mrad	Receiver bandpass	0.5 nm
Altitude	10 km	Integration time	10s	Signal To Noise/bin	210
Precision (molec/cm^2)	$4x10^{14}$			Accuracy	5-10%

Plans

ID	Task Name	2021 Q2	2021 Q3	2021 Q4	2022 Q1	2022 Q2	2022 Q3	Milestones
1	**Build and test 1018 nm seeded fiber amplifier**							1. Successful demonstration of seeded operation of this stage with ~10 W output
2	**Integration of amplified laser systems with non-linear conversion stages**							2. Successful demonstration of tunable output at ~20 μJ/pulse at 100 kHz. 3. Successful demonstration of the laser system with a laboratory HCHO absorption cell, measuring HCHO absorption with the rotational features at 339 nm.
3	**Receiver and data acquisition**							4. Successful integration and test of receiver optics, telescope detector and data acquisition system.
4	**Ground measurement demonstration**							5. Successful demonstration of open path tests to target with transmitter and receiver.
5	**Reporting**							6. Reporting per program requirements.

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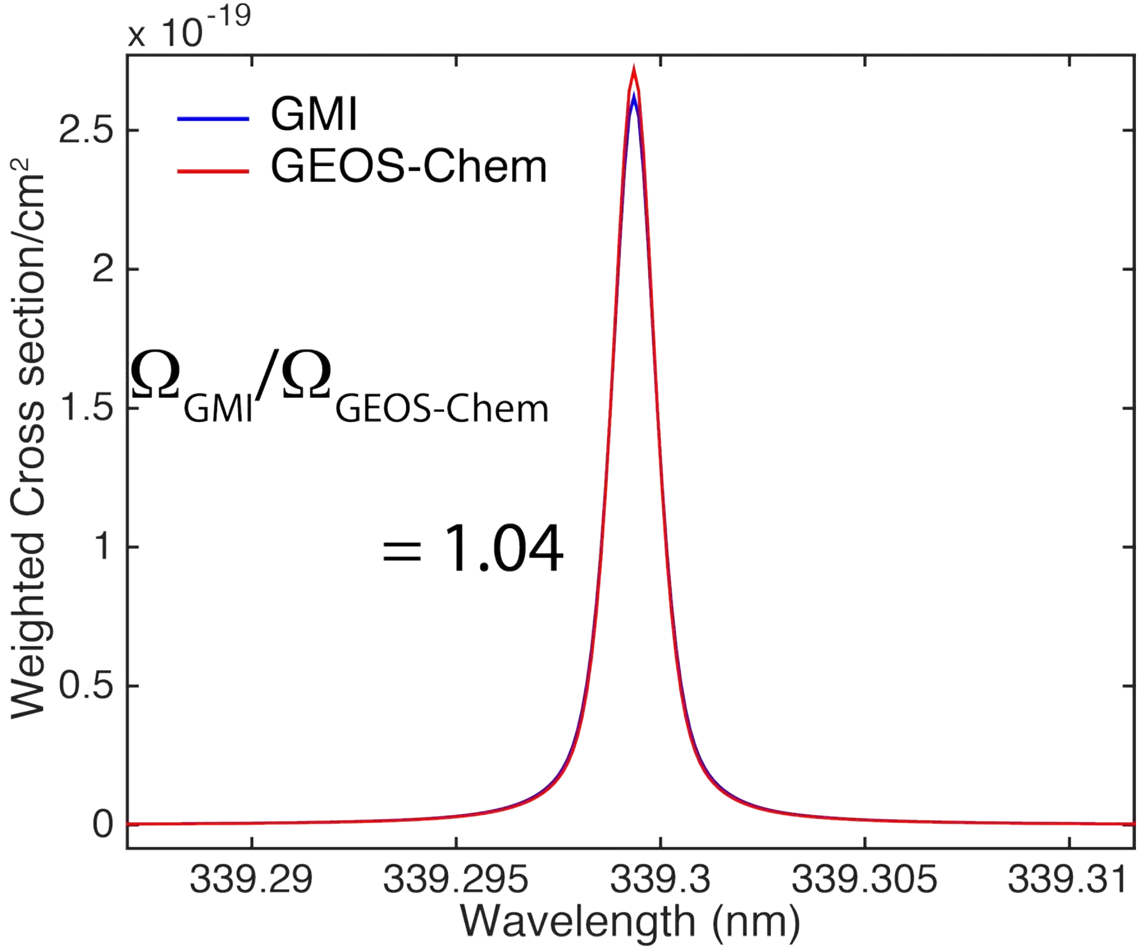
Rotational linestrength is weakly dependent on pressure/temperature Comparison of two different model *a priori*, 30% difference in passive only 4% in active



IPDA is less dependent on the a priori than passive UV